Selective feeding in Keelback snakes *Tropidonophis mairii* in an Australian wetland

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Toad *Bufo marinus* population control is a constant in Australian invasive species management. Predator populations are the most likely group to be affected by the growing number of cane toads (Phillips *et al.* 2003). One of those predators, the Keelback snake *Tropidonophis mairii* is exceptionally resistant to toad toxin and thus able to consume *B. marinus* without immediate adverse reactions (Covacevich and Archer 1975; Shine 1991; Phillips *et al.* 2003). The ability of Keelbacks to consume toads, however, is often confused with toads being a common source of Keelback diet.

Keelbacks only grow to an average size (SVL) of 519 mm (Shine 1991) while toads can grow to 230 mm in body length (Zug and Zug 1979). The small size difference between predator and prey may reduce the number of edible toads. At the same time, it decreases the chance that a Keelback will consume a toad with lethal doses of toxin (Phillips and Shine 2004). A shared habitat may actually be the main reason for toad consumption by Keelbacks rather than a diet preference (Covacevich and Archer 1975). A controlled study showed limited nutritional value of toads for Keelbacks and suggested that optimal foraging behaviour should lead to a feeding preference for native anurans (Llewelyn *et al.* 2009). The aim of this project is to determine feeding habits of Keelbacks in the wild with specific concern to toads.

The study was conducted in the Townsville Town Common, a wetland in tropical North Queensland. The mean maximum temperature can range from 31.2°C in the wet season (December-March) to 26.1°C in the dry season (June-September). Keelbacks were captured during September-Nove mber of 2006, twice a day, once in the morning and again in the evening for six weeks.

Keelbacks were captured using two different methods: road cruising and herp arrays. Road cruising consisted of driving back and forth along the main road of the Townsville Town Common at night at 20-40 kph, with at least two observers, at least four times a week for around four hours a night. The second capture method consisted of 18 T-shaped herp arrays (Fig. 1). This included six funnel traps and four pitfall traps (20L bucket). This set up allowed for other species to be captured and measured for food availability. A wet sponge and a shade cloth were placed in the buckets to keep animals hydrated during peak hours.

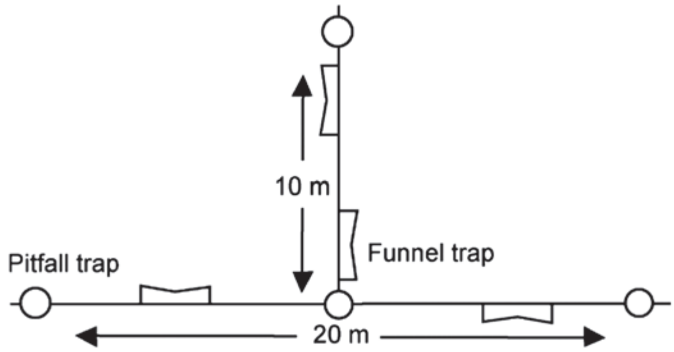

Figure 1. Land array with T- format drift fence including pit trap and funnel locations

Gut contents (indicated by an apparent lump in body) were removed by gently palpating the mass towards the throat causing the contents to be regurgitated. If regurgitation was successful, gut contents were examined and identified where possible.

Using Ivlev's (1977) Electivity Index, diet selectivity was established for Keelbacks in the Town Common comparing abundance of individual frog and toad species to Keelback gut content. The equation for the electivity index is:

$$E^* = (r_i - p_i) / (r_i + p_i)$$

Where r_i is the percent of food class i in the diet and p_i is the percent of food class i in the field. Basically, r_i is the food consumed, while p_i is the food available. The E* value is either greater than 0, meaning the prey item is selected for, or it is less than 0 meaning it is selected against.

Despite the high availability of toads compared to frogs, snakes still consumed more frogs than toads (Table 1). All frog species were considered possible prey items. Only 27 of 110 snakes successfully regurgitated allowing gut contents to be identified; on average one prey item was regurgitated per snake. There were nine frog species (*Litoria bicolor* (n=1), *Litoria caerulea* (n=1), *Litoria fallax* (n=14), *Litoria nasuta* (n=84), *Litoria rothi* (n=2), *Litoria rubella* (n=14), *Limnodynastes convexiusculus* (n=67), *Limnodynastes tasmaniensis* (n=153) and *Opisthodon ornatus* (n=287) available compared to a single species of toad (n=485); however, the toad population was larger than the combined population of all frog species captured. Of the nine species, only four were extracted from gut content; *Limnodynastes* could only be indentified to genus level (Table 1).

Pitfall traps were more efficient than funnel traps at collecting amphibians (ANOVA: $p<0.001$, $n=1108$, $df=1$). There was an assumed bias in trapping methods towards ground dwelling frogs. However, the effects of the bias would be minimal as gut contents collected consisted of ground dwelling frogs only. Seasonal differences would also change the type of prey available, and then perhaps alter the percentage of frogs to toads.

Table 1. Prey available compared to prey consumed by Keelbacks ***Tropidonophis mairii*** in the Town Common. Frogs consists of all frogs captured in the Town Common during the dry season and consumed includes those unidentifiable to species or genus.

Anurans	Available (%)	Consumed (%)
Frogs	44	89
Toads	56	11

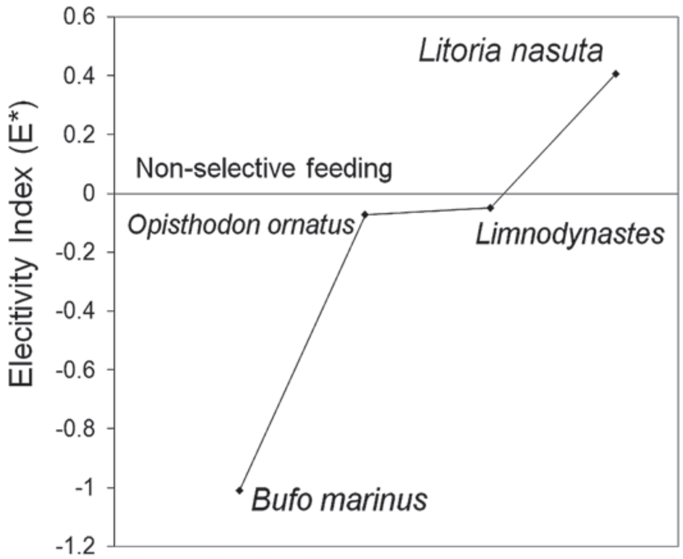

Figure 2. Diet selectivity of Keelbacks by species in the Town Common using an Electivity Index (Ivlev 1977), where E*=0 indicates non-selective feeding. Prey items with a positive E* value are preferred food items, while those with a negative value are avoided.

The diet selectivity index shows frogs were preferred over toads. With respect to individual species: *L. nasuta* was a preferred prey item; *O. ornatus* and the *Limnodynastes* genus values were close to 0, indicating that they are non-selected prey items or eaten in proportion to availability; *B. marinus* was avoided as a prey item (Fig. 2).

Keelbacks are acknowledged as being one of the few species which can consume toads (Covacevich and Archer 1975; Shine 1991). Despite its reputation for consuming toads, Keelbacks do not preferentially prey on toads even though toads are far more abundant than other prey items. When the regurgitated mass was identifiable, it was usually (89%) a frog rather than a toad. This would appear to be in congruence with a previous suggestion that Keelbacks consume toads because they share a similar habitat and not because they are an ideal prey (Covacevich and Archer 1975). Taking into account the high reproductive potential of toads and survivability (Lampo and De Leo 1998) and the seasonally influenced rate at which Keelbacks feed (Brown *et al.* 2002; Brown 2002), Keelbacks are unlikely to have a significant effect on the cane toad population.

Size of prey items plays a large role in influencing prey selection for Keelbacks, as they are gape-limited snakes (Phillips and Shine 2004). The majority of toads caught were similar in size to the larger anurans trapped, however, Keelbacks notably consumed smaller frog species. This could be due to a higher abundance of smaller anurans in the Town Common. However, this limitation from size of prey may render toads only viable Keelback prey for a small portion of their lifetimes.

Keelback snakes are amongst the most common predators on the Town Common. Not only do they opt to not prey on the toad, as preferred prey items feel pressure from the invasive, predation success of the Keelback may be significantly reduced. The toad not only directly affects the Keelback when consumed with its toxin (Llewelyn *et al.* 2009); it will indirectly affect them by out-competing other frogs which are commonly consumed by Keelbacks (Greenlees *et al.* 2006). This could lead to decreased Keelback population and/or increased competition between sympatric snakes for viable prey items. While other natural predators have been identified and many are adapting (Phillips and Shine 2004), Keelbacks do not appear to be major predators on toads, despite the fact that they are one of the only Australian snakes that can eat them.

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